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TECHNICAL MEMORANDUM
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RING SAIL PARACHUTE

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TECHNICAL MEMORANDUM X-232

HIGH-ALTITUDE PERFORMANCE OF A 64-FOOT-DIAMETER RING SAIL PARACHUTE*

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SUMMARY

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Aerial drop tests have been conducted to measure the loads and descent characteristics of a 64-foot-diameter Ring Sail parachute carrying a full-scale orbital capsule. The parachute was deployed from the capsule at 10,000 feet at a terminal velocity of 225 fps. Parachute reefing was varied in the test series and the opening load time histories recorded.

The results show that the parachute when reefed to 10 percent of the nominal parachute diameter for 6 seconds gave the lowest loading time history. Decreasing the reefing time to 4 seconds increased the opening load by 25 percent; a further reduction would eliminate most of the benefit derived from reefing the parachute. Increasing the reefed area of the parachute by factors of 2 and 3 increased the reefed opening load by 30 percent and 80 percent, respectively, over the 10-percent reefing condition. Rate of descent of the parachute and capsule was 33 fps at 5,000 feet and 30.6 fps at sea level. Oscillation of the parachute and capsule was estimated to be $\pm 20^{\circ}$ from the vertical with a period of 5 seconds.

INTRODUCTION

The terminal phase of the manned orbital capsule consists of a parachute system for lowering the capsule with the occupant safely back to earth. This system deploys first a small drogue parachute at high altitudes to stabilize the capsule motion down to altitudes where a main parachute can be deployed. The main parachute reduces the landing impact speed to limits tolerable to the occupant. The parachute system also employs a backup main parachute to be used in case of a failure of the first parachute. This system requires the first parachute to be deployed at an altitude sufficient to allow the occupant to sense a failure, discard the failed main parachute, and deploy the backup parachute.

*Title, Unclassified.

Although parachutes of the size required are used extensively for low-altitude (2,000 to 4,000 feet) cargo aerial drops, little information is available for higher altitude deployments. Altitude effects are such that greatly increased peak opening loads are encountered with increasing altitude. In order to lower these peak loads, the skirt of the parachute may be necked down (reefed) to a smaller diameter for a given time increment. This report contains the results of five tests conducted with a Ring Sail parachute to determine the opening loads with different combinations of reefed diameter and time for an opening altitude of 10,000 feet. These conditions duplicate approximately the proposed condition and technique to be used during the main parachute deployment of the manned orbital capsule. Also obtained during these tests are the rate of descent and the stability or oscillation angles encountered during the parachute descent of the capsule.

APPARATUS AND INSTRUMENTATION

The main parachute tested was a 64-foot-nominal-diameter Ring Sail parachute. Dimensions and details of this parachute are given in figure 1.

In order to measure the parachute loads, full-scale orbital capsule models approximating the National Aeronautics and Space Administration design were used. (See fig. 2.) The gross weights of the capsules were 1,900 and 2,030 pounds during the parachute descent. The center-of-gravity location of the 2,030-pound capsule was $11\frac{3}{4}$ inches behind the maximum diameter station; the lighter capsule had approximately the same center-of-gravity location. The drag stabilization parachute used was a 6-foot-diameter FIST ribbon-type parachute utilizing a three-point suspension system attached to the top canister as shown in figure 3. The main parachute terminated in a single center-located attachment point on the capsule as shown in figure 4. Reefing of the parachute was accomplished by standard reefing-line methods described in reference 1.

Parachute opening loads were measured with a strain-gage tensiometer mounted between the capsule and the parachute riser lines as shown in figure 4. Static-pressure measurements were obtained with a pressure cell located within the capsule and connected to the atmosphere through a pressure manifold system to three locations spaced symmetrically about the capsule; one orifice is shown in figure 4. Both the load and the pressure measurements were recorded on film by standard NASA flight recording equipment located within the capsule.

Parachute stability data were obtained by ground and air photographic coverage of the drop.

Rates of descent were obtained from the static-pressure source and also by radar tracking of the capsule during its descent.

DESCRIPTION OF TEST

The tests were conducted by dropping the instrumented capsule from an Air Force Tactical Air Command C-130 airplane on the radar range at the NASA Wallops Station. Ground radar was used to direct the airplane into position for the drop and to give the drop order. The airplane maintained an indicated speed of 120 knots at an altitude of 15,000 feet while being directed into position for releasing the capsule.

After release, the capsule, mounted on a sled as shown in figure 5, gravity-fed out of the airplane over conveyor rollers. Static lines on the airplane armed all circuits in the capsule, started the capsule instruments, and armed several 2-second-delay pyrotechnic line cutters mounted on the lines holding the sled to the capsule. During the sled-capsule separation, another static line on the capsule arms a 2-second-delay pyrotechnic device that deploys the parachute shown on the sled in figure 5. The sled parachute was needed to keep the sled at a higher altitude than the capsule during the test.

After sled separation, the drag stabilization parachute was deployed by a 5-inch-diameter mortar located in the top jettisonable parachute canister section. This parachute is also used to deploy the main parachute. This action is accomplished by allowing the drag parachute to pull the top-canister section away after releasing this section by a timer-circuit firing of the explosive release bolt shown in figure 4. A static line tied between this section and the main parachute deployment bag pulls the parachute free of the capsule and deploys the parachute. The timer circuit is preset prior to the test to deploy the parachute at an altitude of approximately 10,000 feet. Release of the parachute was initiated upon impact with water by an explosive bolt fired by an electrical circuit which was completed by the salt water.

Cameras on the ground, in the C-130 airplane, and in two Air Force Tactical Air Command T-33 jet chase airplanes photographed the descent, the parachute deployment, and the recovery of the capsule. The jet airplanes used a tandem altitude system, the higher airplane being at the drop altitude and the lower airplane being at the altitude at which the main parachute opened. Both of these airplanes carried a photographer using hand-held motion-picture cameras. This aerial coverage system proved satisfactory in the test.

Radar coverage was obtained separately from an SCR-584 and an FPS-16 radar set. Both systems employed X-, Y-, and Z-axes plotboard information to facilitate ground control of the vehicles employed during the test. Time, azimuth angle, elevation angle, and range information measured by the radar during the capsule descent was recorded on film for later determination of the rate of descent of the capsule.

After impact the capsules were retrieved by Marine Corps helicopters; both an HUS type and an HR2S type were employed during these tests. The helicopter utilized a pickup bail on the top of the capsule which was engaged by a Marine Corps crewman with a hand-held hook.

Two boats were stationed at the drop scene to retrieve the main parachute, the top canister portion of the capsule, and the 6-foot-diameter drogue parachute. One boat was equipped with a small boom capable of lifting the capsule out of the water and transporting the capsule back to land if the helicopter pickup proved unsuccessful.

RESULTS AND DISCUSSION

A total of five aerial test drops were made with the parachute system previously described. All the test drops were made from an altitude of 15,000 feet. After a stabilized fall to approximately 10,000 feet, the main parachute was deployed. Terminal velocity of the capsule at 10,000 feet with the stabilization parachute was 225 fps; this value was determined from the radar tracking data. A summary of other pertinent parameters are as follows:

Test drop	Weight of capsule during parachute descent, lb	Reefing time, sec	Approximate reefed diameter	
			In ft	In percent [1] D_o
1	1,900	6	6.4	10
2	2,030	6	6.4	10
3	1,900	6	9.0	14
4	2,030	4	6.4	10
5	1,900	6	10.8	17

[1] D_o is the nominal diameter of the parachute.

Test drops 1 and 2 were made with identical conditions to give values for comparisons with drops 3 to 5. The load time histories measured during these test drops are shown in figure 6. Both parachutes produce almost identical time histories; the reefed opening loads (parachute tension loads) were 3,800 pounds and the opening loads were

4,700 pounds, well below the 10,000-pound design load of the parachute. Two seconds were required to build up to a peak reefed opening load; deceleration back to approximately 1g (2,000 pounds) required another 4 seconds. The total of 6 seconds is thus a minimum reefing time for the reefed diameter used to give the minimum opening load.

A short reefing time is desirable for the parachute system of the manned orbital capsule due to consideration of aborted launches at low altitudes. Test drop 4 was made with a 4-second reefing time (and the same reefed diameter as test drops 1 and 2) to show the penalty a compromise in reefing time will cost in increased load. Figure 7 shows the measured loads obtained on test drop 4 compared with those obtained with the 6-second reefing time (test drop 2). The 2-second compromise increased the opening shock load by 25 percent; the reefed opening loads remained approximately the same. A further reduction in reefing time would eliminate most of the benefit derived from reefing the parachute.

In order to give the load characteristics of the parachute with differing reefed diameters, test drops 3 and 5 were made with the reefed diameters increased. (See fig. 8.) In test drop 3, the parachute had a reefed area twice that in test drops 1 and 2; in test drop 5, the parachute had a reefed area triple that in test drops 1 and 2. As shown in figure 8, doubling the reefed area increased the reefed opening load by 30 percent; tripling the area increased the load by 80 percent.

Rates of descent were obtained from two separate sources, the radar-tracking information and the static-pressure source. Radiosonde data obtained within several hours of the drop time enabled corrections to be made to give rates of descent based on a standard ICAO day. The rates of descent measurements agreed for each drop test. For a standard day and corrected for a 2,000-pound load, the rate of descent was 33 fps at an altitude of 5,000 feet. At sea level, the rate of descent was 30.6 fps.

Stability of the parachute and capsule was estimated from the photographic coverage taken during the descent. An oscillation of approximately $\pm 20^{\circ}$ from the vertical with a period of 5 seconds was estimated in this manner. No appreciable rotation of the capsule was noted during these tests.

CONCLUSIONS

A total of five aerial drop tests were conducted with a 64-foot-diameter Ring Sail parachute lowering a full-scale orbital capsule weighing approximately 2,000 pounds. The parachutes were deployed at 10,000 feet at a terminal velocity of 225 fps. The parachute reefing conditions were varied during the test series to give information on the loads imposed on the parachute and capsule during high-altitude parachute deployments. Rates of descent and parachute stability were also obtained.

The results show the following conclusions:

1. A reefed diameter of 10 percent of the parachute nominal diameter and 6 seconds duration produced the lowest loading time history. The reefed opening load was 3,800 pounds and the opening load was 4,700 pounds.

2. Decreasing the reefing time to 4 seconds duration added approximately 25 percent to the opening load. A further reduction would eliminate most of the benefit derived from reefing the parachute.

3. Increasing the reefed diameter from 10 percent to 14 percent of the parachute nominal diameter, which represents a doubling of the reefed area, increased the reefed opening load by 30 percent. A further increase in reefed diameter from 10 percent to 17 percent of the parachute nominal diameter, which represents a tripling of the reefed area, increased the reefed opening load by 80 percent.

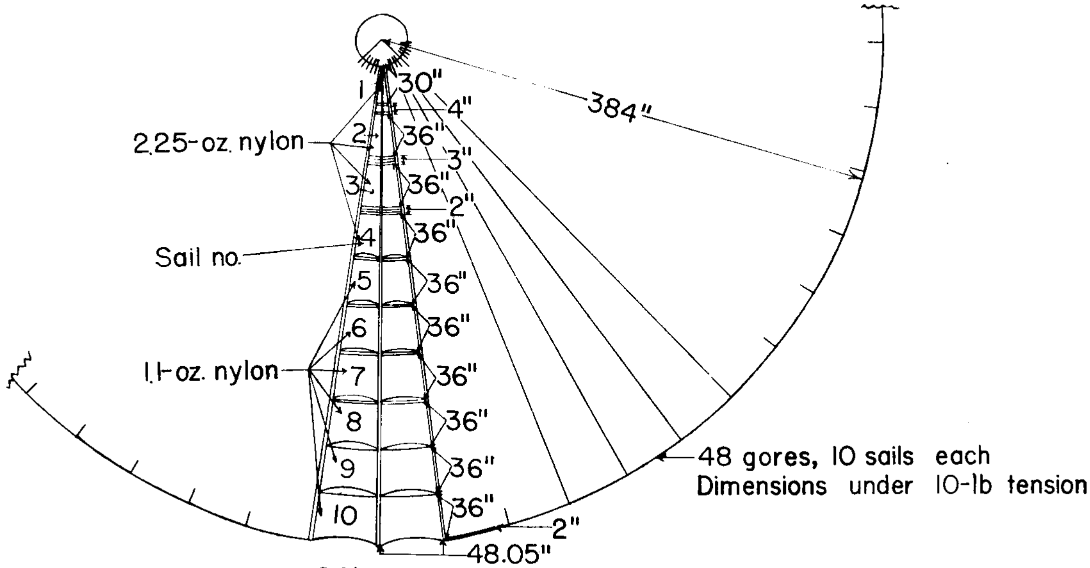
4. Rate of descent of the 64-foot-diameter parachute loaded to 2,000 pounds was 33 fps at 5,000 feet and 30.6 fps at sea level.

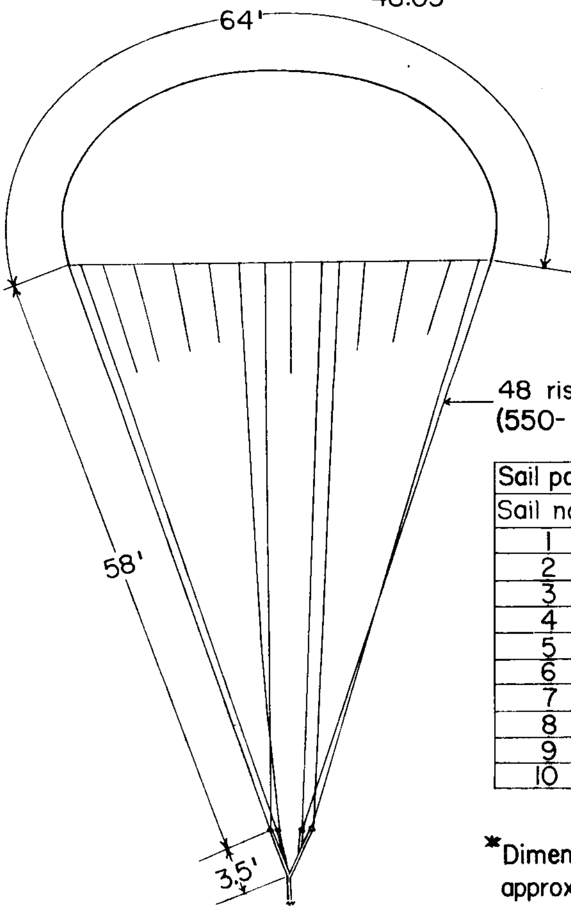
5. Parachute oscillation angles were estimated to be $\pm 20^{\circ}$ from the vertical with a period of 5 seconds.

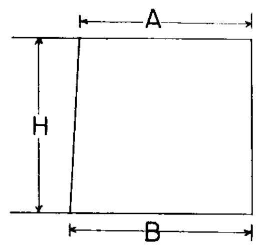
Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., August 18, 1959.

REFERENCE

1. Anon.: United States Air Force Parachute Handbook. WADC Tech. Rep. 55-265, ASTIA Doc. No. AD 118036, U.S. Air Force, Dec. 1956.







Sail pattern dimensions, in.			
Sail no.	H	*A	*B
1	32	4 1/8	8 7/16
2	36 1/2	8 31/32	13 21/32
3		14 1/32	18 1/2
4		18 3/4	24 5/16
5		23 1/32	29
6		27 3/32	33 11/16
7		31 3/32	38 9/32
8		34 25/32	42 13/32
9		38 5/16	46 1/8
10		41 19/32	49 9/16

*Dimensions A & B are reduced by approximately 1 1/2" after sewing

Figure 1.- Details and dimensions of the Ring Sail parachute.

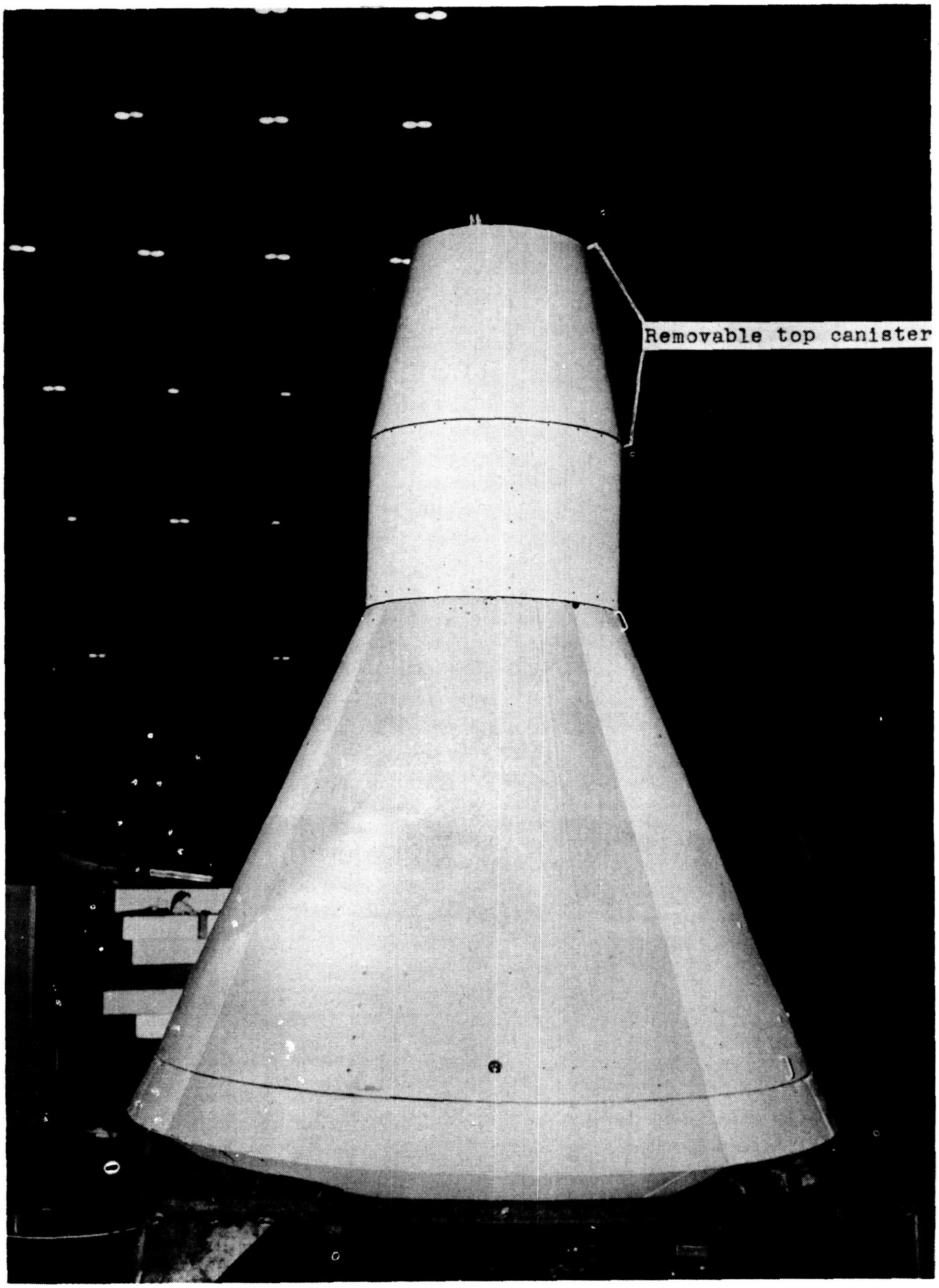


Figure 2.- Capsule used for tests. L-59-2170.1

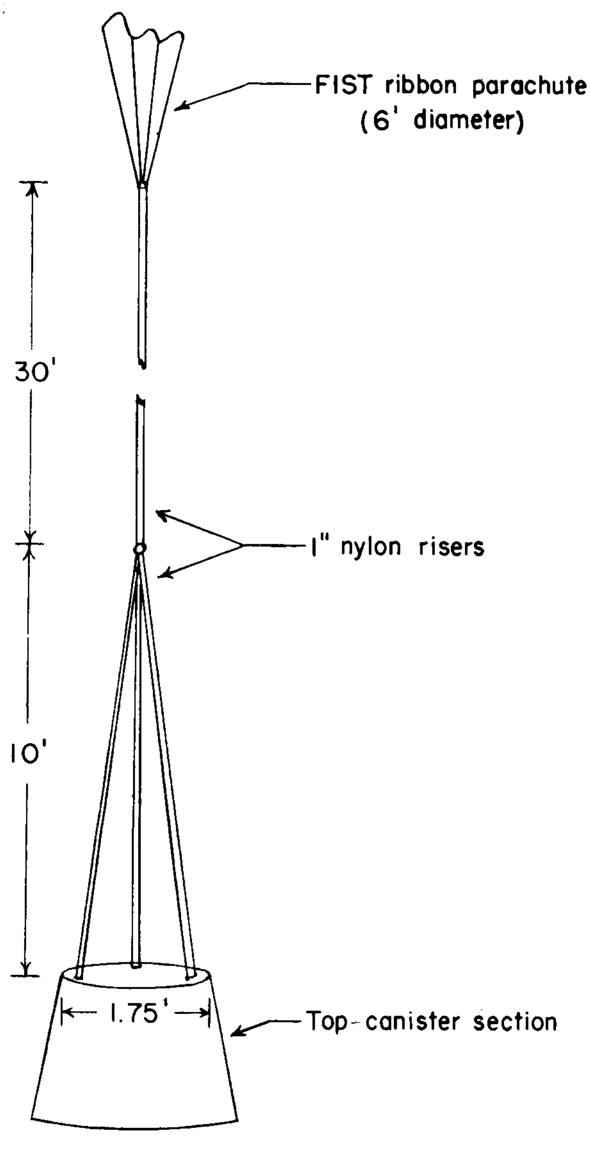
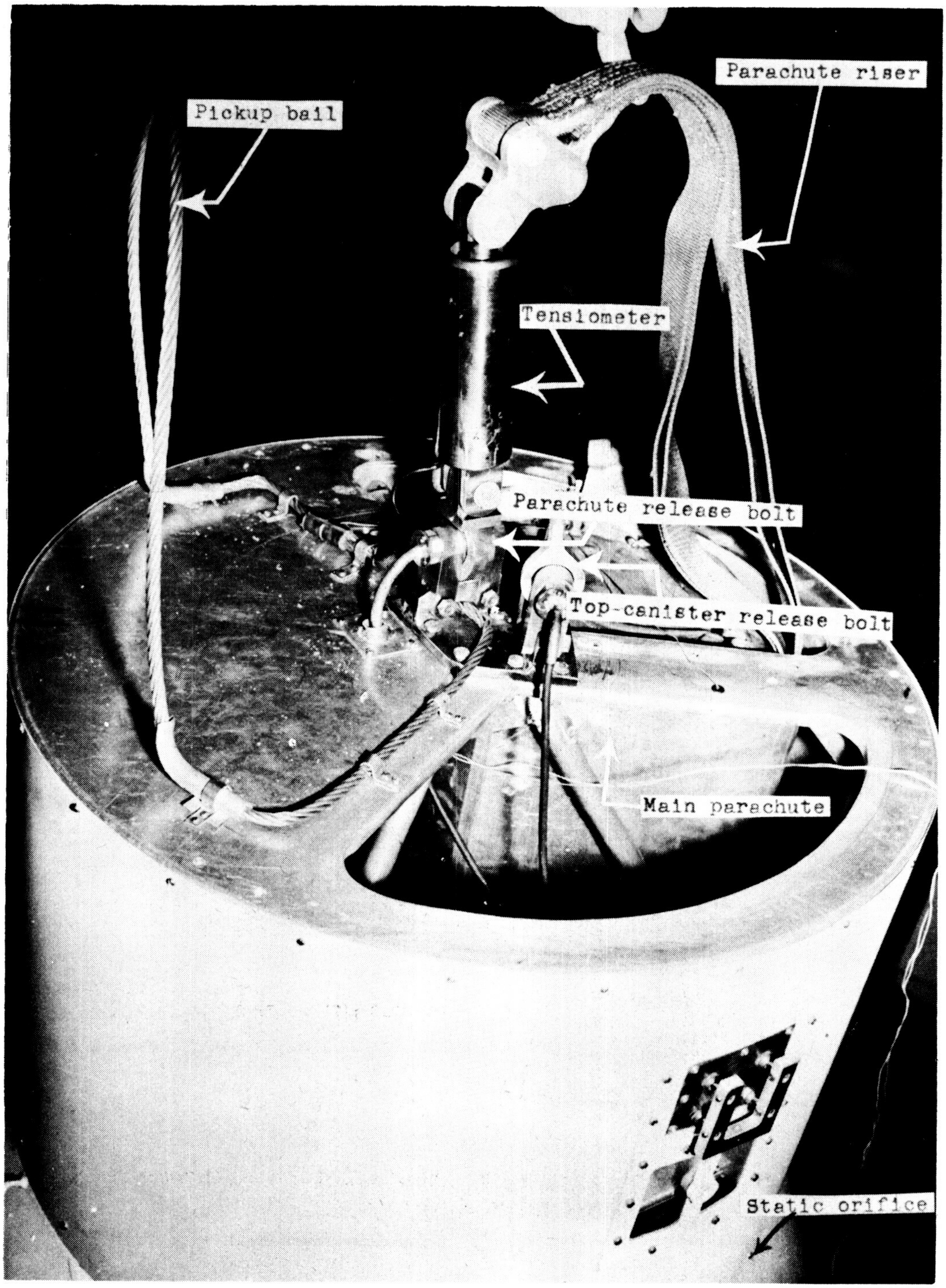


Figure 3.- Details of the drogue stabilization attachment to the top canister.



L-59-2193.1
Figure 4.- Details of the capsule with the top canister removed.

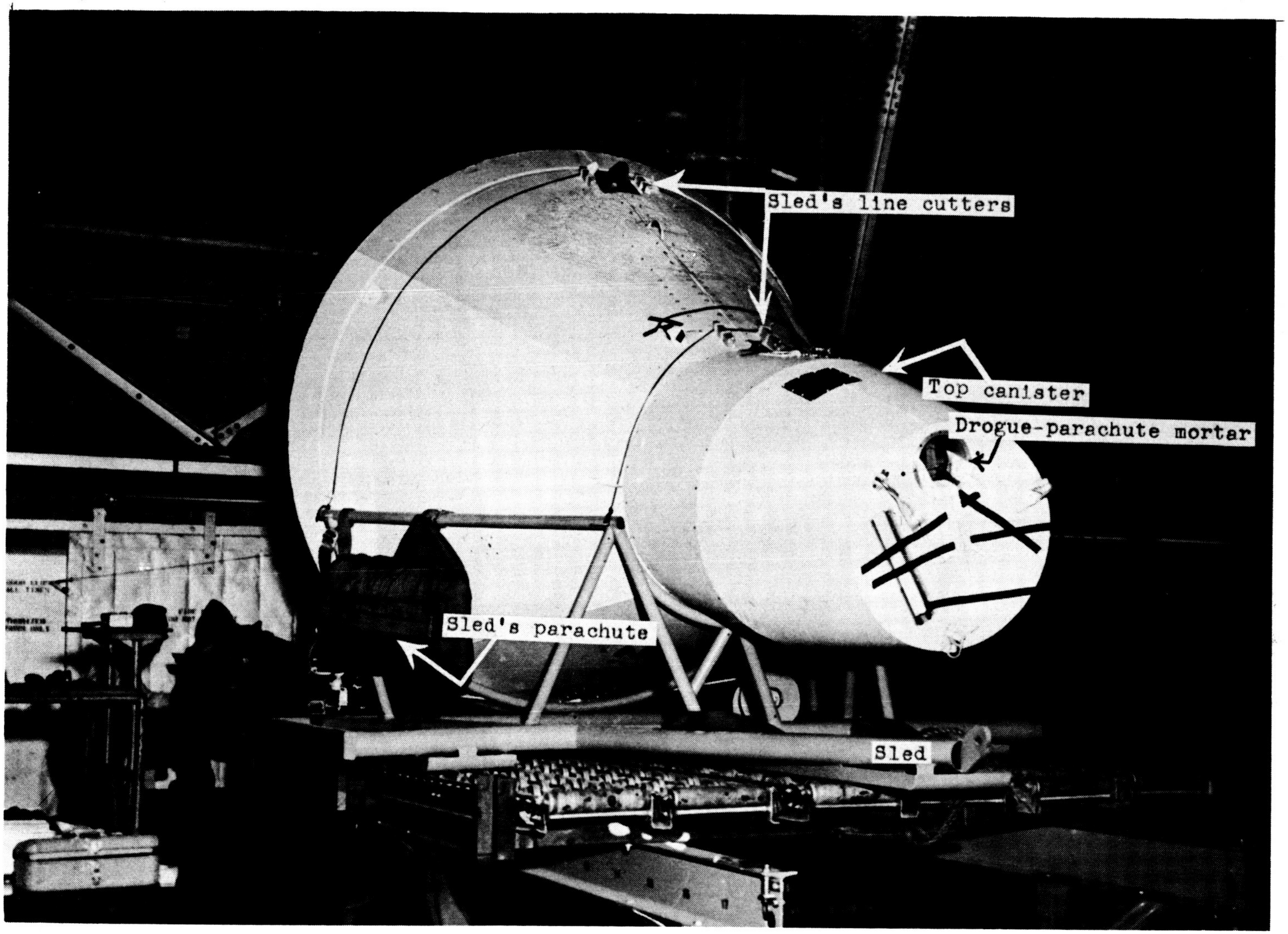


Figure 5.- Capsule mounted on the sled. L-59-2175.1

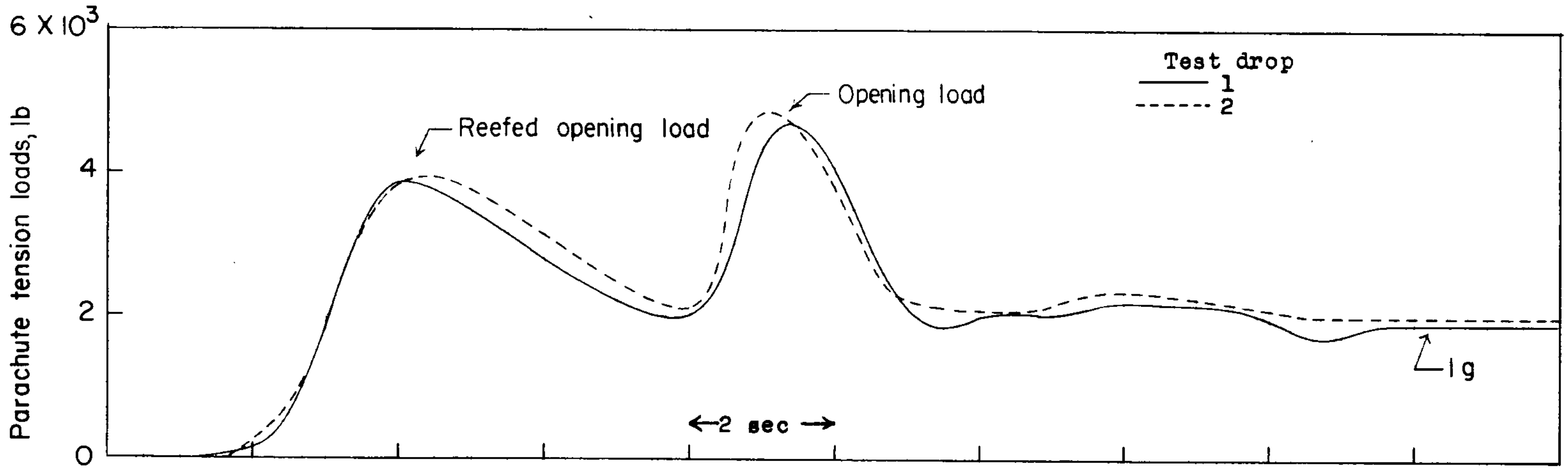


Figure 6.- Measured opening loads with 6 seconds of reefing time and 10-percent-nominal-diameter reefing.

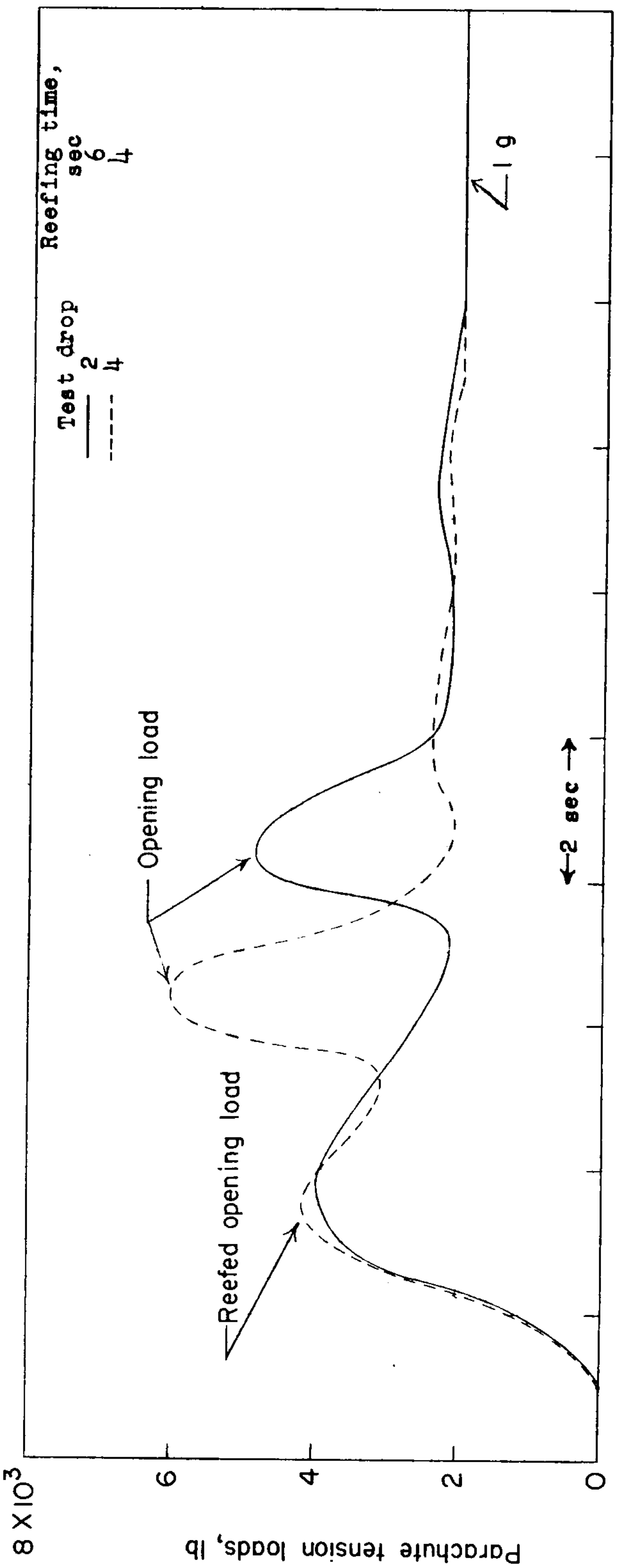


Figure 7.- Comparison showing the loads with changes in reefing time and 10-percent-nominal-diameter reefed parachute.

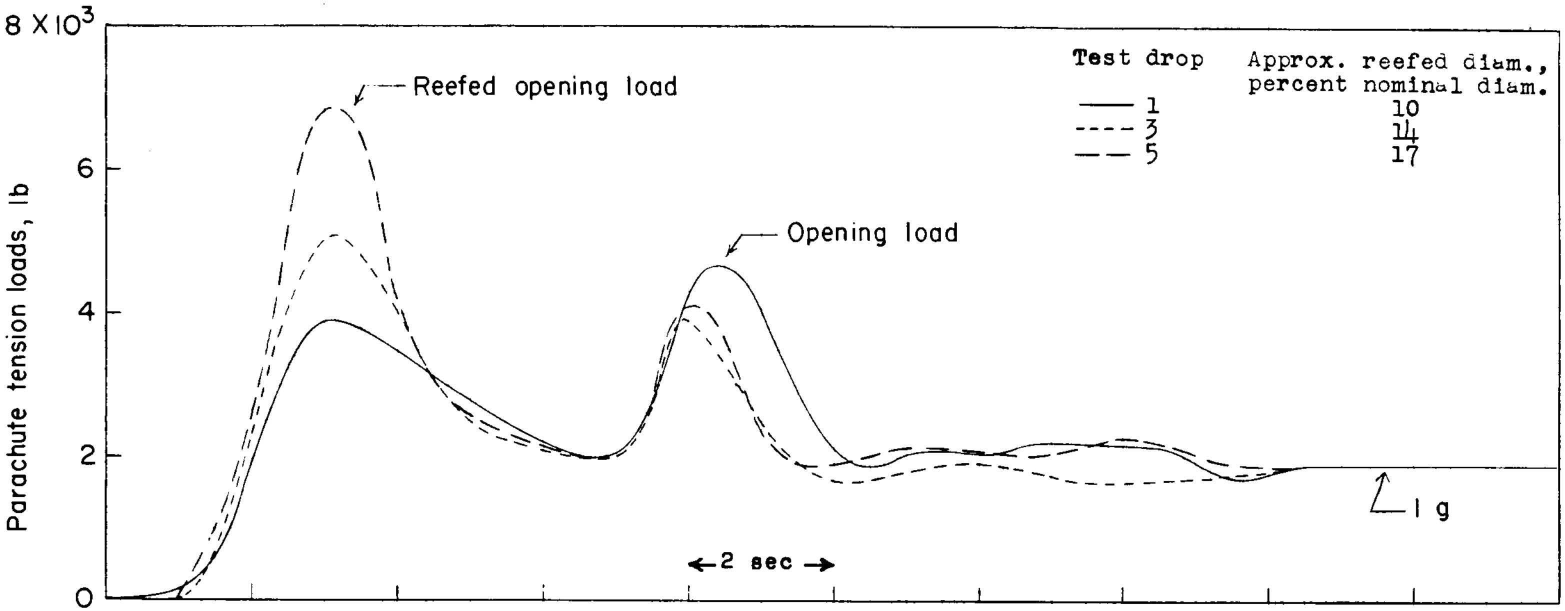


Figure 8.- Comparison showing the loads with changes in reefed diameter and a 6-second reefing time.